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# Heat Tolerance in Two Tropically Adapted *Bos taurus* Breeds, Senepol and Romosinuano, Compared with Brahman, Angus, and Hereford Cattle in Florida<sup>1</sup>

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**ABSTRACT:** Two trials were conducted with heifers to determine heat tolerance among temperate *Bos taurus* (Angus, Hereford), *Bos indicus* (Brahman), tropical *Bos taurus* (Senepol, Romosinuano), and the reciprocal crosses of Hereford and Senepol. Differences among breeds in temperament score, circulating concentrations of cortisol, and blood packed cell volume were also investigated. Trial 1 used 43 Angus, 28 Brahman, 12 Hereford, 23 Romosinuano, 16 Senepol, 5 Hereford × Senepol (H × S), and 5 Senepol × Hereford (S × H) heifers. Trial 2 used 36 Angus, 31 Brahman, 9 Hereford, 14 Senepol, 19 H × S, and 10 S × H heifers. On the hottest summer date in Trial 1, rectal temperature of Angus was greater ( $P < .001$ ) than that of Brahman, Senepol, or Romosinuano. Rectal temperature and plasma cortisol were significantly less in Senepol than in Brahman, suggesting that the differences in rectal temperature between these breeds may be due to differences in stress response possibly related to differences in temperament. Reciprocal crosses of Hereford and Senepol had rectal temperatures nearly as low as that of Senepol and displayed substantial heterosis ( $-9.4\%$ ,  $P < .05$ ) in  $\log_{10}$  rectal temperature on the hottest summer date. On both the hottest and coolest dates in Trial 1, Angus heifers had significantly faster respiration rates than Brahman, Romosinuano, or Senepol heifers,

and Brahman had significantly slower respiration rates than Romosinuano or Senepol. On the hottest summer date in Trial 2, rectal temperature in Angus heifers was greater ( $P < .001$ ) than in Brahman or Senepol heifers. Reciprocal crosses of Hereford and Senepol had rectal temperatures similar to that of Senepol, and heterosis for  $\log_{10}$  rectal temperature was similar to that in Trial 1 ( $-9.8\%$ ,  $P < .05$ ). Considering rank order among breeds, Brahman always had the slowest respiration rate and greatest packed cell volume. Brahman had significantly greater temperament scores and plasma cortisol concentrations than Angus or Senepol, except that plasma cortisol was not different between Brahman and Senepol on the hottest summer date. On this date, rectal temperature did not differ between Brahman and Senepol, which supports the hypothesis that there is a relationship between response to stress and rectal temperature that helps explain differences in rectal temperature between Brahman and Senepol. The results of these trials demonstrate heat tolerance of the Senepol and Romosinuano, two *Bos taurus* breeds. Furthermore, the results suggest a substantial level of dominance of the Senepol's ability to maintain constant body temperature in a hot environment as measured by rectal temperature in crosses with a non-adapted breed.

Key Words: Beef Breeds, Cattle, Heat Tolerance, Subtropics, Temperament, Temperature

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## Introduction

In contrast to the abundance of beef cattle genotypes in the United States that are adapted to temperate climates, germplasm sources with adaptation to warm climates are generally limited to the Zebu breeds (*Bos indicus*), primarily the American Brahman. Several traits of the Brahman have a negative impact on their acceptability to some cattle producers: reproductive and feedlot performance, carcass quality including meat tenderness, temperament, and neonate survivability (Turner, 1980). Because of this negative impact on acceptability, crossbred feeder calves phenotypically displaying Brahman breeding are often discounted by cattle buyers. Finch (1983, 1986) reviewed the differences in body temperature regulation between *Bos indicus* and temperate *Bos taurus* breeds and the importance of these differences to beef cattle production in warm environments. However, there are few reports, other than de Alba and Sampaio (1957) and Spiers et al. (1994), regarding body temperature regulation in *Bos taurus* breeds native to the American tropics.

The primary objective of this study was to investigate rectal temperature and respiration rate, indices of heat tolerance, among temperate *Bos taurus* (Angus, Hereford), *Bos indicus* (Brahman), tropical *Bos taurus* (Senepol, Romosinuano), and the reciprocal crosses of Hereford and Senepol. Differences among these breeds in temperament score, circulating concentrations of cortisol, and blood packed cell volume (PCV) were also investigated to help explain potential differences in rectal temperature and respiration rate among these breeds.

## Materials and Methods

**Location.** Trials were conducted at the Subtropical Agricultural Research Station near Brooksville, FL (28°33'30" north latitude and 82°23'3" west longitude). The topography is gently rolling hills; the highest elevation is 84 m. Average annual rainfall is 1,372 mm, with 54% occurring in June, July, August, and September. Average year-round temperature is approximately 22°C, with chances of frosts occurring from November through March, the coolest months of the year.

**Trial 1.** For this trial, 132 heifers were used: 43 Angus (310 ± 5.3 kg), 28 Brahman (301 ± 6.6 kg), 12 Hereford (319 ± 10.1 kg), 23 Romosinuano (289 ± 7.3 kg), 16 Senepol (332 ± 8.8 kg), 5 Hereford × Senepol (**H** × **S**; 360 ± 15.7 kg), and 5 Senepol × Hereford (**S** × **H**; 341 ± 15.7 kg). Heifers were approximately 18 mo old at the start of the trial. The Romosinuano were imported from Costa Rica (Centro Agronomico Tropical de Investigacion y Enseñanza, Turrialba) as cryopreserved embryos in 1990 and were born to

Angus and Brahman surrogate dams. All other heifers were produced as a part of the regular breeding programs at Brooksville. Heifers were grazed on bahiagrass (*Paspalum notatum*) pastures with free access to water and a mineral supplement (guaranteed analysis: NaCl, 25 to 32%; Ca, 15 to 18%; P, 5 to 8%; Fe ≥ .9%; F ≤ .15%; Cu ≥ .1%; Co ≥ .01%; Se, .0010 to .0015%). From mid-November to the first of April, heifers were given ad libitum access to bahiagrass hay. From mid-November to mid-May, heifers also were fed 4.5 kg·heifer<sup>-1</sup>·d<sup>-1</sup> of rhizoma peanut (*Arachis glabrata*) hay, and from December 3 to mid-May they were fed 1.8 kg·heifer<sup>-1</sup>·d<sup>-1</sup> of molasses.

Measurements were conducted at weekly intervals on three warm season (referred to as summer) and three cool season (referred to as winter) dates in 1992: August 5, August 12, August 19, November 17, November 24, and December 1. On each date, heifers were gathered by 1000 and kept in holding pens to rest with access to shade until 1200 when heifers were worked individually through a squeeze chute for collection of blood samples and measurements of rectal temperature and respiration rate. Heifers had been worked in these facilities on several previous occasions. Precise time required to work all of the heifers and the order of handling each heifer was recorded. Before and after working of heifers each date and at some intermediate times, ambient temperature (mercury thermometer), relative humidity (sling psychrometer), and black globe temperatures (shaded and unshaded; Hertig, 1968; Buffington et al., 1981) were recorded. Average values were considered to be the mean of all measurements taken for each date. For each date, a temperature-humidity index (**THI**; West, 1994) was calculated from the average ambient temperature and average relative humidity. Rectal temperature measurements were made with electronic thermometers (Vet III, Advanced Animal Instruments, Williston Park, NY). Respiration rates were obtained by observing flank or rib cage movements while heifers were in a squeeze chute, usually with their head restrained but with the squeeze released enough to allow normal breathing patterns to be observed. Blood was collected by jugular venipuncture into a 9-mL blood collection system (Monovette®; Sarstedt, Newton, NC) that provided 1.6 mg of EDTA/mL of blood. The blood tubes were placed on ice until they were transported to the laboratory, where blood samples were centrifuged to obtain plasma that was stored at -20°C for later analysis of cortisol and progesterone. Cortisol was analyzed by RIA (Godfrey et al., 1991) using a commercially available kit (no. 031, Pantex, Santa Monica, CA). Intra- and inter-assay CV were 9.4 and 9.5%, respectively.

Heifers were worked on two other dates, August 26 and December 8, to obtain additional blood samples for plasma progesterone analysis only. Concentrations of progesterone in plasma were determined by ELISA

(Elmore, 1989) using commercially available kits (Ovasure® progesterone EIA kit, Cambridge Veterinary Sciences, Cambs, U.K.). Intra- and interassay CV were 10.2 and 17.1%, respectively. Results of these analyses were used to assess whether heifers were in estrus at the time rectal temperature and respiration rate measurements were obtained. Heifers were considered to be near estrus if progesterone concentration was less than 2.0 ng/mL on the day the measurement was taken and greater than 2.0 ng/mL 1 wk later.

Heifer BW were obtained before the summer measurements on July 29, between summer and winter measurements on October 14, and in the spring following winter measurements on March 3 or 10. Average daily gain was calculated for both intervals and for the entire period of July through March.

**Trial 2.** A second trial was conducted with 119 heifers: 36 Angus ( $335 \pm 4.8$  kg), 31 Brahman ( $346 \pm 5.1$  kg), 9 Hereford ( $365 \pm 9.5$  kg), 14 Senepol ( $337 \pm 7.6$  kg), 19 H  $\times$  S ( $394 \pm 6.6$  kg), and 10 S  $\times$  H ( $367 \pm 9.1$  kg). As in Trial 1, heifers were approximately 18 mo old at the start of the trial. A protocol similar to that for Trial 1 was used with measurements conducted in 1993: August 11, August 18, August 25, November 17, November 24, and December 2. The two additional dates for blood progesterone analysis were September 1 and December 8. Heifers in this trial grazed rhizoma peanut pasture in the summer and fall and then were managed as in Trial 1 through the winter and spring. Bahiagrass and rhizoma peanut hay feeding began December 2, and molasses feeding began December 20. All supplemental feeding except for mineral was discontinued April 7.

In addition to rectal temperature and respiration rate measurements, temperament was scored on a 1 to 5 scale with the following definitions as used by

Kunkle et al. (1986): 1 = nonaggressive (docile)—walks slowly, can approach closely, not excited by humans or facilities; 2 = slightly aggressive—runs along fences, will stand in corner if humans stay away, may pace fence; 3 = moderately aggressive—runs along fences, head up and will run if humans move closer, stops before hitting gates and fences, avoids humans; 4 = aggressive—runs, stays in back of group, head high and very aware of humans, may run into fences and gates even with some distance, will likely run into fences if alone in pen; and 5 = very aggressive—excited, runs into fences, runs over humans and anything else in path, “crazy.” Also, as an index of oxygen carrying capacity, PCV was measured before plasma was obtained for cortisol and progesterone analyses.

Heifer BW were obtained before the summer measurements on August 4, between summer and winter measurements on October 27, and in the spring following winter measurements on March 2 or 10. Average daily gain was calculated as in Trial 1.

**Statistical Analysis.** Warm weather on some winter measurement dates for both trials (Table 1) precluded meaningful analysis with season (hot summer vs cool winter) as an independent variable. Initial analyses of rectal temperature, respiration rate, temperament score, PCV, and plasma cortisol used a model appropriate for repeated measures. With these analyses, there were breed  $\times$  date of measurement interactions for all variables except cortisol in Trial 2. Therefore, final analyses of breed effects were conducted by date for each trial as one-way ANOVA using the GLM procedure of SAS (1985). In Trial 1, degrees of freedom for breed were divided into the following contrasts: Angus vs Brahman, Angus vs Romosinuano, Angus vs Senepol, Brahman vs

Table 1. Ambient conditions, Trial 1 (1992) and Trial 2 (1993)

Trial/date	Ambient temp., °C	Relative humidity, %	Black globe temp. shade, °C	Black globe temp. no shade, °C	Temp. humidity index <sup>a</sup>
Trial 1:					
Aug 5	25.0	89.0	26.0	28.0	76
Aug 12	26.5	84.0	27.8	30.0	78
Aug 19	32.8	64.5	33.5	44.8	85
Nov 17	20.3	72.0	21.0	23.0	66
Nov 24	27.8	67.8	29.0	34.0	78
Dec 1	18.3	56.0	18.3	27.0	63
Trial 2:					
Aug 11	32.0	56.5	32.0	47.5	82
Aug 18	33.5	57.5	33.0	44.0	84
Aug 25	30.5	70.0	30.5	36.5	82
Nov 17	30.0	69.0	28.5	33.5	81
Nov 24	21.5	74.5	21.5	23.5	69
Dec 2	24.0	60.0	23.5	30.5	71

<sup>a</sup>Dry bulb temperature in °F – (.55 – .55 relative humidity expressed as a decimal) (dry bulb temperature – 58) (West, 1994).

Table 2. Effects of breed on variables related to heat tolerance in heifers, Trial 1 (1992)<sup>a</sup>

Date	Variable	Breed										Contrast <sup>b</sup>				H, S vs H × S, S × H
		Angus (A)	Brahman (B)	Hereford (H)	Romosinuano (R)	Senepol (S)	H × S	S × H	A vs B	A vs R	A vs S	B vs R	B vs S	B vs S	B vs S	
Aug 19	n	43	28	12	23	16	5	5	—	—	—	—	—	—	—	—
	Rectal temp., °C	40.4	39.6	40.2	39.5	39.2	39.3	39.5	—	—	—	—	—	—	—	—
	Log rectal temp. <sup>c,d</sup>	.54 ± .008	.41 ± .010	.51 ± .015	.40 ± .011	.34 ± .013	.37 ± .023	.40 ± .023	***	***	***	NS	***	***	***	*
	Respiration rate, bpm <sup>e</sup>	69 ± 1.9	36 ± 2.4	64 ± 3.6	55 ± 2.6	57 ± 3.1	63 ± 5.6	56 ± 5.6	***	***	***	***	***	***	***	NS
Dec 1	Plasma cortisol <sup>f</sup> , ng/mL	17.8 ± 1.61	29.1 ± 2.00	17.4 ± 3.06	32.8 ± 2.21	21.8 ± 2.65	20.8 ± 4.74	31.2 ± 4.73	***	***	NS	NS	*	NS	NS	NS
	n	43	28	11	23	15	4	4	—	—	—	—	—	—	—	—
	Rectal temp., °C	39.5	39.6	39.2	39.2	39.0	39.1	39.3	—	—	—	—	—	—	—	—
	Log rectal temp. <sup>c,d</sup>	.39 ± .009	.40 ± .01	.35 ± .017	.35 ± .012	.30 ± .014	.32 ± .028	.35 ± .028	NS	**	***	***	***	***	***	NS
Jul-Oct <sup>h</sup>	Respiration rate, bpm <sup>e</sup>	51 ± 1.3	30 ± 1.7	45 ± 2.5	39 ± 1.7	37 ± 2.1	45 ± 4.1	44 ± 4.1	***	**	***	***	***	*	NS	NS
	Plasma cortisol <sup>f</sup> , ng/mL	18.3 ± 1.84	35.6 ± 2.38	16.1 ± 3.55	29.6 ± 2.46	21.7 ± 3.05	19.9 ± 5.93	20.9 ± 5.90	***	***	NS	†	***	***	***	NS
	ADG, kg/d	.10 ± .032	.38 ± .039	.28 ± .063	.31 ± .043	.34 ± .054	.31 ± .104	.47 ± .104	***	***	***	NS	NS	NS	NS	NS
	ADG, kg/d	.01 ± .025	.18 ± .033	.08 ± .055	.16 ± .034	.03 ± .042	.14 ± .082	-.12 ± .082	***	***	NS	NS	NS	**	NS	NS
Oct-Mar <sup>i</sup>	ADG, kg/d	.04 ± .018	.25 ± .024	.14 ± .040	.21 ± .025	.14 ± .031	.20 ± .060	.09 ± .060	***	***	**	NS	NS	**	NS	NS
	ADG, kg/d															

<sup>a</sup>Least squares means.<sup>b</sup>P < .10, \*P < .05, \*\*P < .01, \*\*\*P < .001, NS = not significant.<sup>c</sup>Adjusted for order of handling, P < .001.<sup>d</sup>Log10 (rectal temperature - 37.0).<sup>e</sup>Breaths (respirations) per minute.<sup>f</sup>Adjusted for order of handling, P < .05.<sup>g</sup>Adjusted for order of handling, P < .01.<sup>h</sup>July 29, 1992, to October 14, 1992.<sup>i</sup>October 14, 1992, to March 3 or 10, 1993.

July 29, 1992, to March 3 or 10, 1993.



Romosinuano, Brahman vs Senepol, and Hereford + Senepol vs  $H \times S + S \times H$ . In Trial 2, the contrasts were Angus vs Brahman, Angus vs Hereford, Angus vs Senepol, Brahman vs Senepol, and Hereford + Senepol vs  $H \times S + S \times H$ . When statistically significant, order of handling was included as a covariate except for analysis of PCV. Before analysis of rectal temperature, data were transformed by taking the  $\log_{10}$  of the difference between measured rectal temperature and 37.0°C (Turner, 1982). For reporting purposes, least squares means also were calculated from similar analyses of untransformed data. In separate analysis of all dependent variables, estrus (0 or 1) was used as a covariate.

## Results and Discussion

Ambient conditions for each date in Trials 1 and 2 are given in Table 1. Rank order among dates of ambient temperature, black globe temperature in shade, and THI were similar. Black globe temperature integrates dry bulb temperature with convection and radiation effects. Black globe temperatures with no shade on some dates were only slightly greater than black globe temperatures taken in the shade due to overcast conditions on those days. Heat stress associated with an average THI above 72 has resulted in reduced milk yield in dairy cows (Johnson, 1987). In both trials, THI exceeded 72 during all summer measurement dates and during one of the three winter measurement dates.

**Trial 1.** One each of Hereford, Senepol,  $H \times S$ , and  $S \times H$  heifers were removed from this trial and slaughtered between the summer and winter measurement dates for purposes of another study. Effects of breed on rectal temperature, respiration rate, and plasma cortisol are given in Table 2. To facilitate the illustration of interactions between measurement date and breed, data were selected based on THI and black globe temperature for the hottest (August 19) and coolest (December 1) dates. Average time to handle each heifer was 1.6 min on August 19 and 1.7 min on December 1. Order of handling affected rectal temperature ( $P < .001$ ) and plasma cortisol ( $P < .05$ ) on August 19, and affected respiration rate ( $P < .001$ ) and plasma cortisol ( $P < .01$ ) on December 1. Order of handling effects on rectal temperature have been previously reported (Lofgreen, 1979; Hammond and Olson, 1994).

The most common index of heat tolerance in cattle is core body temperature as measured by rectal temperature, which is moderately heritable. Some estimates of heritability of rectal temperature in beef cattle are .11 (da Silva, 1973), .25 (Turner, 1982), and .33 (Turner, 1984). In this study, Angus heifers were used to represent a temperate *Bos taurus* breed, and the Angus data in this trial were contrasted with

Brahman, Romosinuano, and Senepol data. On the hottest summer date, rectal temperature in Angus was greater ( $P < .001$ ) than rectal temperature in these other three breeds. On the coolest winter date, rectal temperatures were not different between Angus and Brahman, but were still greater in Angus than in Romosinuano ( $P < .01$ ) or Senepol ( $P < .001$ ). Although significant, the magnitude of these differences in winter was not great (.3 to .5°C).

Mean rectal temperature in Senepol was less ( $P < .001$ ) than in Brahman on both dates. We previously reported lower rectal temperatures for Senepol than in Brahman (Hammond and Olson, 1994). Therefore, we expanded the current study to include analysis of circulating cortisol concentrations in an effort to determine whether this difference between tropically adapted breeds could be due to a difference in stress response (i.e., indirectly due to differences in temperament). Environmental heat exposure can cause a transient increase in circulating glucocorticoids that may subsequently decrease even though body temperature remains elevated during chronic heat exposure (Christison and Johnson, 1972; Alvarez and Johnson, 1973; Rhynes and Ewing, 1973). Stress of handling cattle also can cause an increase in circulating glucocorticoids (Venkateseshu and Estergreen, 1970; Crookshank et al., 1979). Consistent with the concept that chronic heat exposure does not increase circulating glucocorticoids, in the present trial breed differences in plasma cortisol were similar between summer and winter measurement dates. Angus heifers had lower ( $P < .001$ ) plasma cortisol than Brahman heifers, which is consistent with previous reports of experiments with steers. In one study, Angus steers had lower plasma cortisol concentrations than Brahman  $\times$  Angus steers (Blecha et al., 1984). In a similar study, Angus  $\times$  Hereford steers had lower plasma cortisol concentrations than Brahman  $\times$  Angus or Brahman  $\times$  Hereford steers (Zavy et al., 1992). However, some experiments with cows (Stahringer et al., 1994) and bulls (Berardinelli et al., 1992; Chase et al., 1995a) have failed to demonstrate greater circulating cortisol in Brahman. Plasma cortisol was significantly less in Senepol than in Brahman, and this finding supports our hypothesis (Hammond and Olson, 1994) that the differences in rectal temperature between these breeds may be due to differences in stress response related to differences in temperament. Senepol are known to have a docile temperament (Hupp, 1981), whereas Brahman are known to "become aroused more quickly" and "are difficult to handle under forced or stress working conditions" (Turner, 1980). The Romosinuano is also a *Bos taurus* breed developed in the tropics (Primo, 1990), as was the Senepol (Hupp, 1981). On the August 19 measurement date, there was no difference in rectal temperature or plasma cortisol concentration between Romosinuano heifers and Brahman heifers. However,

on the December 1 measurement date, rectal temperature was less ( $P < .001$ ) in Romosinuano than in Brahman, and this was related to a trend ( $P < .10$ ) toward lower plasma cortisol.

In an experiment with calves, we observed that rectal temperatures during summer were similar in Senepol and  $H \times S$  and that rectal temperatures in Senepol,  $H \times S$ , and  $S \times H$  were less ( $P < .01$ ) than in Hereford (Hammond and Olson, 1994). In the present study, we tested the heterotic effects between Hereford and Senepol for rectal temperature in heifers. There was a  $-9.4\%$  heterosis ( $P < .05$ ) in  $\log_{10}$  rectal temperature on the hottest summer measurement date (August 19). This heterosis level was achieved as a result of the crossbreds being nearly as heat tolerant as the Senepol. On the coolest winter measurement date, there was no significant difference between the average of rectal temperatures for Hereford and Senepol compared with the average for their reciprocal crosses.

Although the association of heat tolerance with panting in cattle has been shown to vary among individuals (Bianca, 1963), Robertshaw (1987) suggested that respiration rate, as a measure of panting, may be a more appropriate indicator of heat stress than rectal temperature. Respiration rates were slower in winter (December 1) than in summer (August 19), but Angus heifers had significantly greater respiration rates than Brahman, Romosinuano, and Senepol heifers on both dates. Brahman had significantly slower respiration rates than Romosinuano and Senepol irrespective of date of measurement. Brahman seemed to display deeper respirations, however, so it is uncertain whether Brahman had lower minute respiratory volume (tidal volume  $\times$  respiration rate). Turner (1980) attributed the lower respiration rate in Brahman to differences in certain hematological variables. Brahman cattle have higher PCV and erythrocyte number compared with British *Bos taurus* breeds (Evans, 1963; Howes, 1963; Gutierrez-De La R. et al., 1971) and this suggests a greater oxygen-carrying capacity consistent with lower respiration rate. There was no difference in respiration rate between the average of Hereford and Senepol heifers compared with the average of their reciprocal crosses.

In a study with post-puberal heifers, estrus was associated with a sustained rise in body temperature of  $\geq .3^\circ\text{C}$  ranging from 4 to 21 h (Mosher et al., 1990). Estrus in the present trial was associated with an overall increase ( $P < .001$ ) of  $.23^\circ\text{C}$  in rectal temperature; however, only a few heifers were near estrus on each measurement date (three on August 19 and three on December 1). Estrus had no effect on rank order of rectal temperature among breeds or on the significance of the breed contrasts tested.

During the relatively warm period from July 29 to October 14, Angus heifers gained less ( $P < .001$ ) than Brahman, Romosinuano, or Senepol heifers. There

were no differences in ADG between Brahman and Romosinuano or Senepol during this period. The Angus were smaller framed cattle than the other breeds, so the differences in ADG were not necessarily a reflection of differences in heat tolerance. This concept is supported by slower ( $P < .001$ ) gains in Angus compared with Brahman and Romosinuano also during the relatively cooler period of October 14 through March 3 or 10. The ADG in Senepol during the cooler period was not different from that for Angus and was less ( $P < .01$ ) than that for Brahman. The number of crossbred Hereford and Senepol heifers in this trial was limited, and consequently there was no demonstration of heterosis for ADG during either the warm or cool period. However, in a larger study with steers we found substantial levels of heterosis for post-weaning performance traits, including ADG (10.6%), for these breeds (Chase et al., 1995b).

**Trial 2.** As in Trial 1, data are presented for the hottest (August 18) and coolest (November 24) measurement dates (Table 3). Average times required to handle each heifer were similar to those for Trial 1: 1.4 min on August 18 and 1.5 min on November 24. Order of handling had significant effects on rectal temperature, respiration rate, and temperament score on both dates but did not affect plasma cortisol on either date.

On the hottest summer date, rectal temperature in Angus heifers was greater ( $P < .001$ ) than for Brahman or Senepol heifers, as in Trial 1, and was not different from that in Hereford heifers. Unlike in Trial 1, Senepol rectal temperatures were not less than those for Brahman on this date, but tended ( $P < .10$ ) to be less on the coolest date. Rectal temperature remained significantly greater in Angus heifers compared with Brahman or Senepol heifers on November 24, but rectal temperatures in Angus were not appreciably elevated higher than  $39^\circ\text{C}$  as they were on August 18. As in Trial 1, the reciprocal crosses of Hereford and Senepol exhibited rectal temperatures nearly as low as that for Senepol, and heterosis for  $\log_{10}$  rectal temperature also was similar to that in Trial 1 ( $-9.8\%$ ,  $P < .05$ ).

As in Trial 1, Angus had higher ( $P < .001$ ) respiration rates than Brahman or Senepol on both dates. Respiration rate in Angus was not different from that in Hereford on August 18, but tended ( $P < .10$ ) to be faster in Angus on November 24. As in Trial 1, respiration rate in Brahman on the warmest date was slower ( $P < .01$ ) than in Senepol, but did not differ between Brahman and Senepol on the coolest date. Considering rank order of respiration rate among breeds, Brahman was always the slowest. To determine whether the relationship between differences in respiration rate and differences in oxygen-carrying capacity between temperate *Bos taurus* and Brahman was similar to that between tropical *Bos taurus* and Brahman, we measured PCV. On August

Table 3. Effects of breed on variables related to heat tolerance in heifers, Trial 2 (1993)<sup>a</sup>

Date	Variable	Breed					Contrast <sup>b</sup>					
		Angus (A)	Brahman (B)	Hereford (H)	Senepol (S)	H × S	S × H	A vs B	A vs H	A vs S	B vs S	H, S vs H × S,
Aug 18	n	36	31	9	14	19	10	—	—	—	—	—
	Rectal temp. <sup>c</sup> , °C	40.1	39.2	40.2	39.1	39.3	39.5	—	—	—	—	—
	Log rectal temp. <sup>cd</sup>	.49 ± .011	.34 ± .012	.51 ± .022	.31 ± .017	.35 ± .015	.39 ± .022	***	—	***	NS	*
	Respiration rate <sup>e</sup> , bpm <sup>e</sup>	73 ± 1.8	37 ± 2.0	76 ± 3.6	46 ± 2.9	62 ± 2.5	66 ± 3.6	***	NS	***	**	NS
	Plasma cortisol, ng/mL	28.4 ± 2.62	39.4 ± 2.82	26.1 ± 1.23	45.5 ± 4.81	30.0 ± 3.61	34.0 ± 5.24	***	NS	***	NS	NS
	Temperament score <sup>ef</sup>	2.0 ± .08	3.0 ± .09	1.6 ± .17	1.9 ± .13	1.7 ± .12	2.1 ± .17	***	*	NS	***	NS
	Packed cell volume, %	32.1 ± .45	35.8 ± .48	31.3 ± .90	34.4 ± .72	33.8 ± .62	33.8 ± .90	***	NS	**	†	NS
Nov 24	n	36	31	9	14	19	10	—	—	—	—	—
	Rectal temp. <sup>c</sup> , °C	39.3	39.0	39.2	38.8	38.9	38.9	—	—	—	—	—
	Log rectal temp. <sup>cd</sup>	.35 ± .012	.29 ± .013	.33 ± .024	.25 ± .019	.26 ± .017	.27 ± .023	**	NS	***	†	NS
	Respiration rate <sup>e</sup> , bpm <sup>e</sup>	51 ± 1.4	37 ± 1.6	46 ± 2.8	41 ± 2.3	45 ± 2.0	40 ± 2.7	***	†	***	NS	NS
	Plasma cortisol, ng/mL	18.7 ± 2.31	36.9 ± 2.49	19.4 ± 4.62	25.4 ± 3.71	20.7 ± 3.27	25.5 ± 4.39	***	NS	NS	*	NS
	Temperament score <sup>ef</sup>	2.2 ± .095	2.5 ± .106	2.1 ± .188	2.1 ± .152	1.8 ± .133	2.3 ± .180	*	NS	NS	*	NS
	Packed cell volume, %	37.1 ± .61	42.0 ± .66	34.6 ± 1.22	37.5 ± .98	37.3 ± .86	37.1 ± 1.16	***	†	NS	***	NS
Aug–Oct <sup>h</sup>	ADG, kg/d	.44 ± .038	.62 ± .040	.44 ± .075	.69 ± .060	.52 ± .052	.61 ± .071	**	NS	***	NS	NS
	ADG, kg/d	-.34 ± .049	.06 ± .052	-.19 ± .097	-.23 ± .079	-.30 ± .067	-.18 ± .092	***	NS	NS	**	NS
	ADG, kg/d	-.04 ± .032	.28 ± .034	.05 ± .062	.12 ± .050	.02 ± .043	.13 ± .059	***	NS	**	*	NS

<sup>a</sup>Least squares means.  
<sup>b</sup>bip < .10, \*P < .05, \*\*P < .01, \*\*\*P < .001, NS = not significant.

<sup>c</sup>Adjusted for order of handling, P < .001.

<sup>d</sup>Log10 (rectal temperature - 37.0).

<sup>e</sup>Breaths (respirations) per minute.

<sup>f</sup>Scored on a 5-point scale (1 = very docile, 5 = very aggressive).

<sup>g</sup>Adjusted for order of handling, P < .01.

<sup>h</sup>August 4, 1993, to October 27, 1993.

<sup>i</sup>October 27, 1993, to March 2 or 10, 1994.

<sup>j</sup>August 4, 1993, to March 2 or 10, 1994.



18, PCV was greater ( $P < .001$ ) in Brahman than in Angus, as expected, and tended ( $P < .10$ ) to be greater in Brahman than in Senepol. On November 24, PCV was greater ( $P < .001$ ) in Brahman than in either Angus or Senepol, suggesting that high PCV is a characteristic of Brahman but not of tropical *Bos taurus* as represented by the Senepol. However, a direct relationship between respiration rate and PCV in Brahman vs Senepol was not evident in this trial. Gutierrez-De La R. et al. (1971) reported that Brahman cattle had significantly higher PCV than Hereford cattle, and, consistent with the present trial, they found no significant effect of ambient temperature (21 vs 32°C) on PCV.

Turner (1980) suggested that disposition may be the most important reason *Bos indicus* cattle are not used more in crossbreeding. In addition to monitoring plasma cortisol concentrations, in this trial we also used a scoring system to evaluate breed differences in temperament. Brahman had significantly greater temperament scores and plasma cortisol concentrations than did Angus or Senepol, except that plasma cortisol was not different between Brahman and Senepol on August 18. On this date, rectal temperature was not different between Brahman and Senepol, which supports the hypothesis that there is a relationship between response to stress and rectal temperature that helps explain when differences in rectal temperature between Brahman and Senepol are or are not observed. Temperament score was greater in Angus heifers than in Hereford heifers on August 18, but there was no difference on November 24. Temperament score was not different between Angus and Senepol on either date.

Eight heifers were near estrus on August 18 and three were near estrus on November 24, but there was no overall effect of estrus on rectal temperature in this trial.

Although not tested statistically, heifer BW gains were faster during the relatively warm period in this trial (August 4 to October 27) than in Trial 1 because of the differences in pasture quality between bahiagrass and rhizoma peanut. However, the cooler period gains were greater in Trial 1, resulting in similar overall rates of gain between trials. Significant differences in ADG between Angus and Brahman, between Angus and Senepol, and between Brahman and Senepol were similar to those observed in Trial 1. Even though there was a larger number of crossbred Hereford and Senepol heifers in this trial compared with Trial 1, we still did not observe heterosis for ADG. Our previous observation of substantial heterosis for ADG with these crosses (Chase et al., 1995b) was with younger animals from weaning to 18 mo of age. Also as in Trial 1, the superior ADG during the warmer period displayed by Brahman and Senepol heifers compared with Angus heifers probably was confounded with frame size. However, because the difference in ADG between Angus and Senepol abated

during the cooler period, the suggestion is that the other indications of heat tolerance are related to differences in production. In support of this, we have previously observed increased grazing time in Senepol compared with Hereford cows under tropical summer conditions in subtropical Florida (Hammond and Olson, 1994).

**Discussion.** Some *Bos taurus* breeds may provide a viable alternative as a source of germplasm with adaptation to the warm, harsh environments of the southern United States if they prove comparable or superior to Brahman in heat tolerance and(or) other economically important traits. The Senepol is a *Bos taurus* breed developed on St. Croix by crossing Red Poll with N'dama cattle from Senegal (Hupp, 1981). The Romosinuano is a *Bos taurus* Criollo breed native to the Sinú region of Colombia (Primo, 1990) and is similar in appearance to the Senepol. Preliminary evidence suggests that carcass quality grade and tenderness is similar for Senepol and Hereford steers finished to a common backfat thickness (Chase et al., 1995b). In a study with 18 Angus and 16 Romosinuano  $\times$  Angus steers and heifers (Clarke et al., 1993), tenderness was similar between breeds and quality grade was similar or better in the crossbreds (breed  $\times$  sex interaction,  $P < .05$ ).

The results of the present trials confirm our previous observations regarding heat tolerance of the Senepol (Hammond and Olson, 1994) and extend these observations to another *Bos taurus* breed, the Romosinuano. The ability of these two *Bos taurus* breeds to maintain rectal temperature near 39°C during summer in the hot, humid environment of central Florida demonstrates a level of heat tolerance similar to that of *Bos indicus* (as represented in this study by Brahman) and greater than that of temperate *Bos taurus* (as represented by Angus). Furthermore, we have confirmed substantial dominance effects for the ability of Senepol to maintain constant body temperature in a hot environment as measured by rectal temperature in its crosses with Hereford. In environmental chamber experiments with six Angus, four Romosinuano, and two Romosinuano  $\times$  Angus calves, similar observations of heat tolerance in Romosinuano and its dominance in F<sub>1</sub> progeny were observed (Spiers et al., 1994).

Although *Bos taurus* as well as *Bos indicus* can display heat tolerance, there are physiological differences between them. When there were differences in rectal temperature between Brahman and Senepol, these differences were related to differences in plasma cortisol concentrations. This observation is not completely consistent with differences in temperament score, because in Trial 2 temperament score was higher in Brahman than in Senepol even when there were no differences in rectal temperature or plasma cortisol. Also, respiration rate in Brahman seems to be characteristically lower than in *Bos taurus* breeds regardless of ambient conditions.

## Implications

Heat-tolerant *Bos taurus* breeds, such as the Senepol and Romosinuano in this study, may provide a viable source of germplasm with adaptation to the warm environments of the southern United States. The consistent expression of heat tolerance, as indicated by the ability to maintain constant body temperature in a hot environment, in crossbred progeny of the Senepol should facilitate use of the Senepol in crossbreeding programs. The Senepol would also contribute a docile temperament relative to Brahman. Further evaluation of these breeds and their crosses for production characteristics is warranted.

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